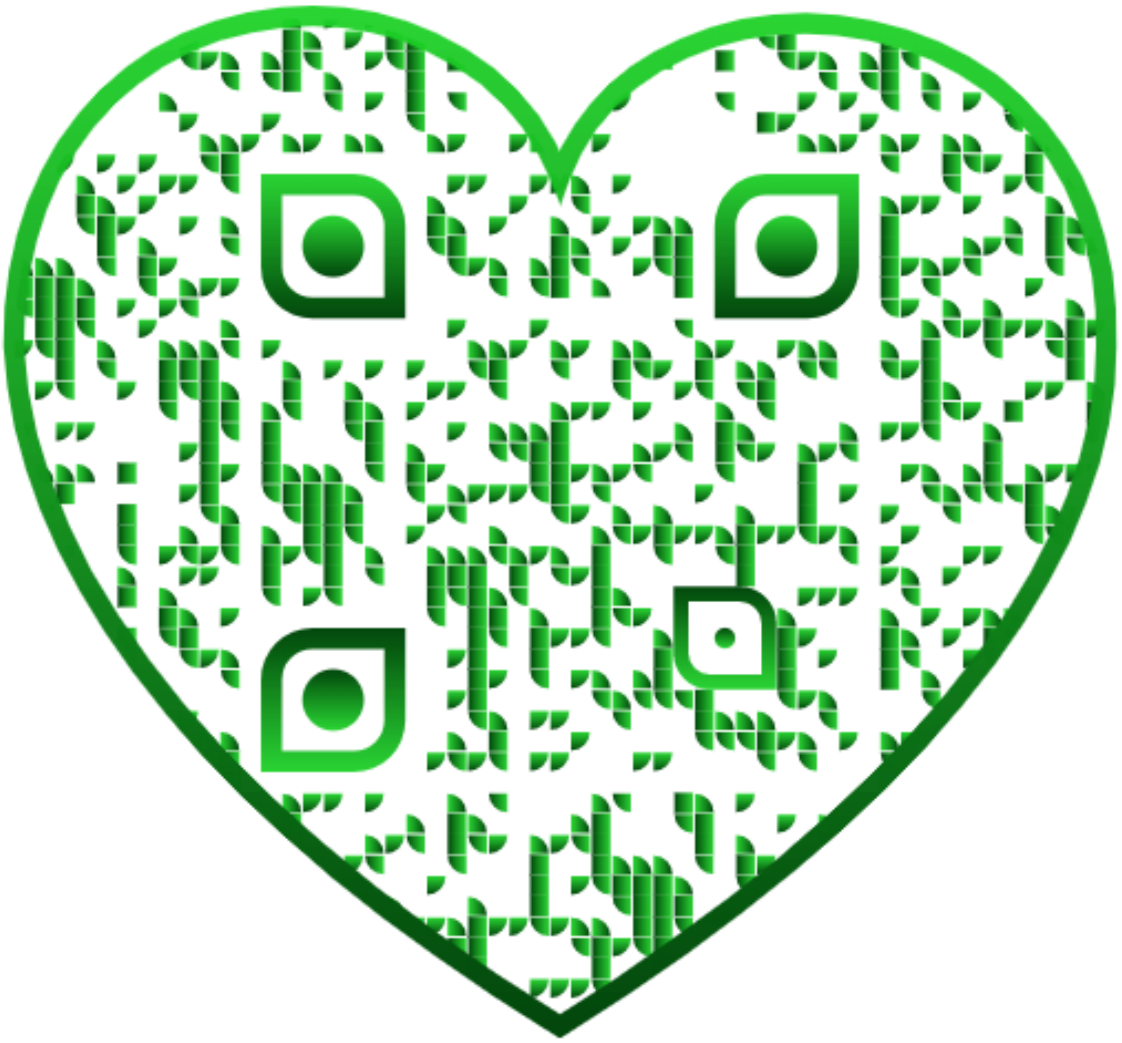
The Search for Extraterrestrial Intelligence



Methods for searching for life

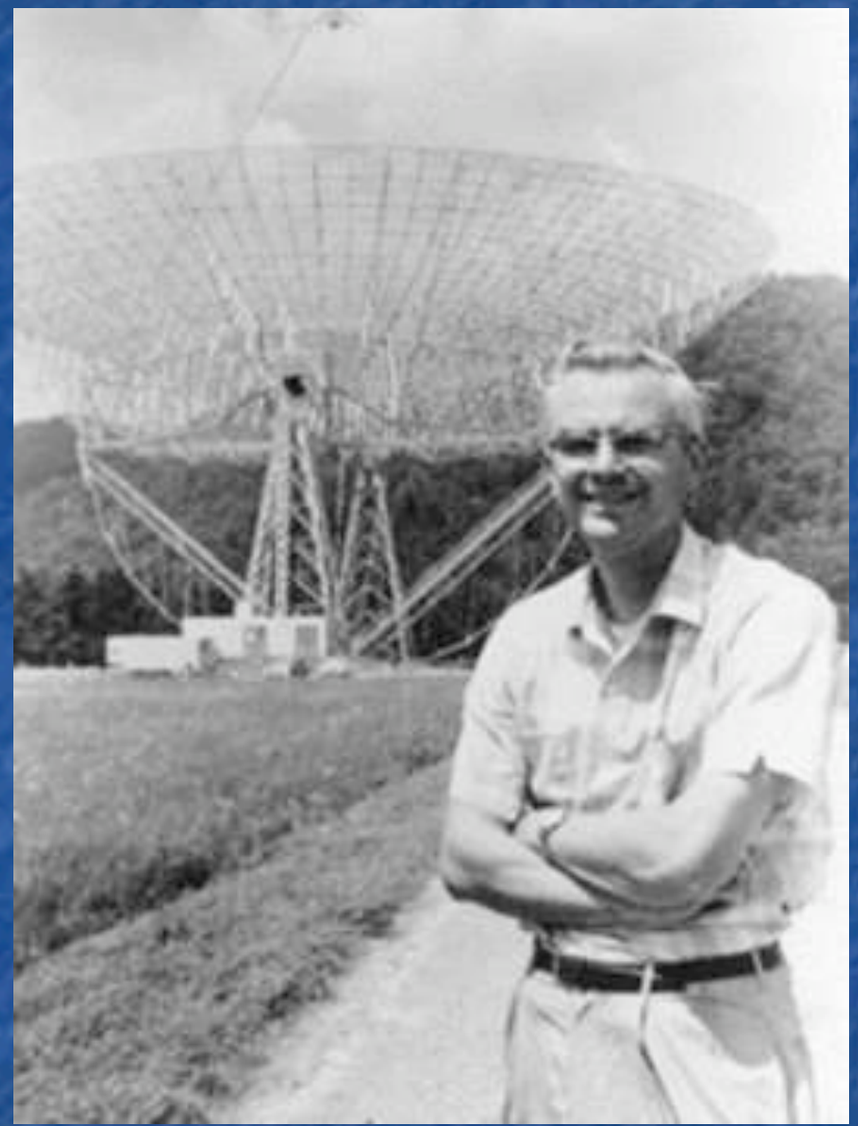
- Direct searches for microbial life in the solar system
  - rovers, sample return missions to Mars, Europa, etc.
- Indirect searches for signs of life in the atmospheres of extra-solar planets
  - biomarkers such as methane, ozone, etc.
- Detection of signals from intelligent civilisations
  - the Search for Extraterrestrial Intelligence (SETI)

Early SETI attempts

- 1901, from the moment radio transmissions were successful, Marconi realized the potential from space
- 1924, when Mars at superior conjunction, Army listening
  - but wrong (low) frequencies
  - which bounce off ionosphere
- Lots of radio interference (thunderstorms, solar flares, Earth-based transmissions)

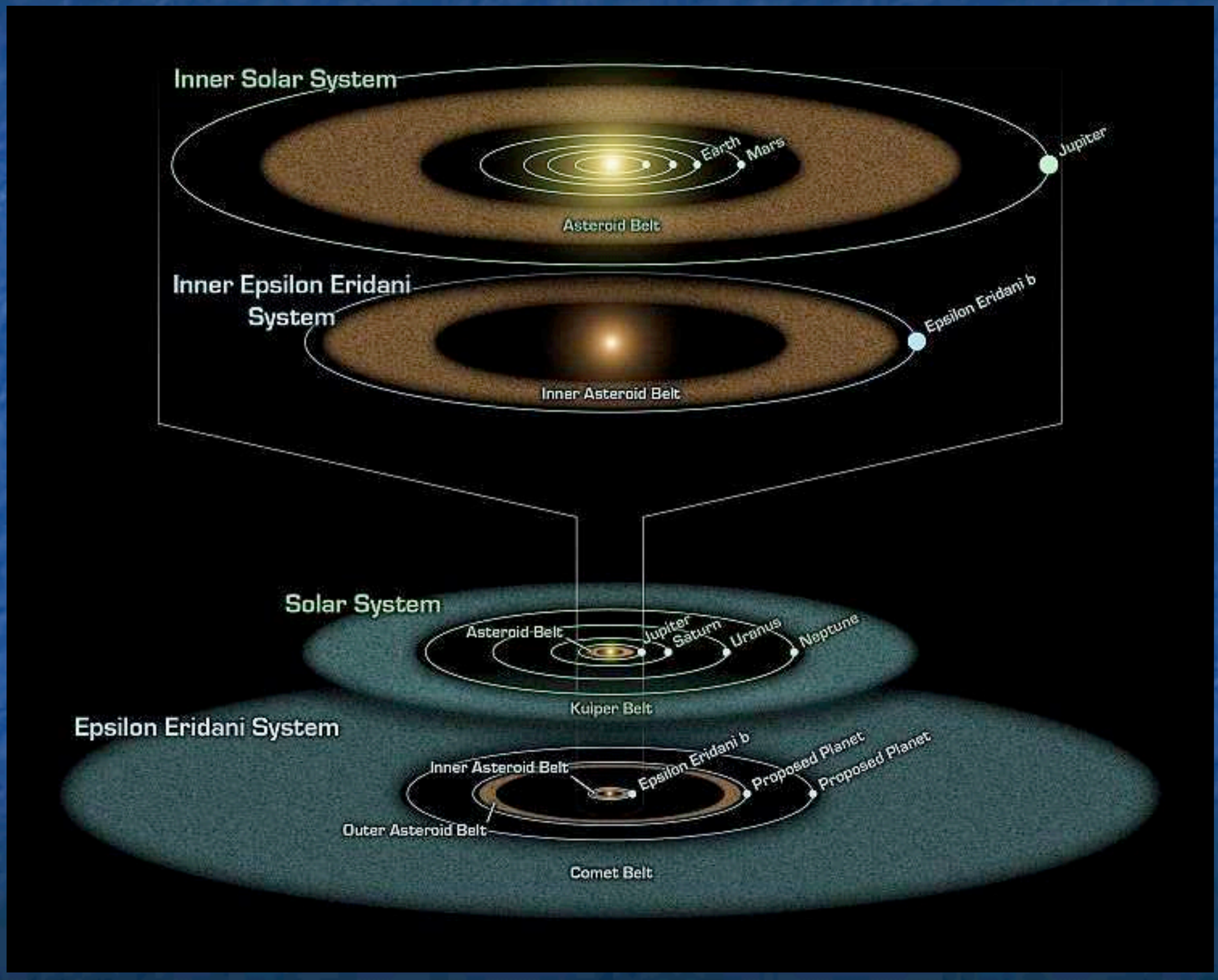
Early SETI attempts

- 1959, proposed to search for beacons at 21cm (1420 MHz)
  - HI emission
- 1960, Frank Drake did
  - Green bank 26-m radio telescope (project Ozma)
  - tau Ceti
  - epsilon Eridani **



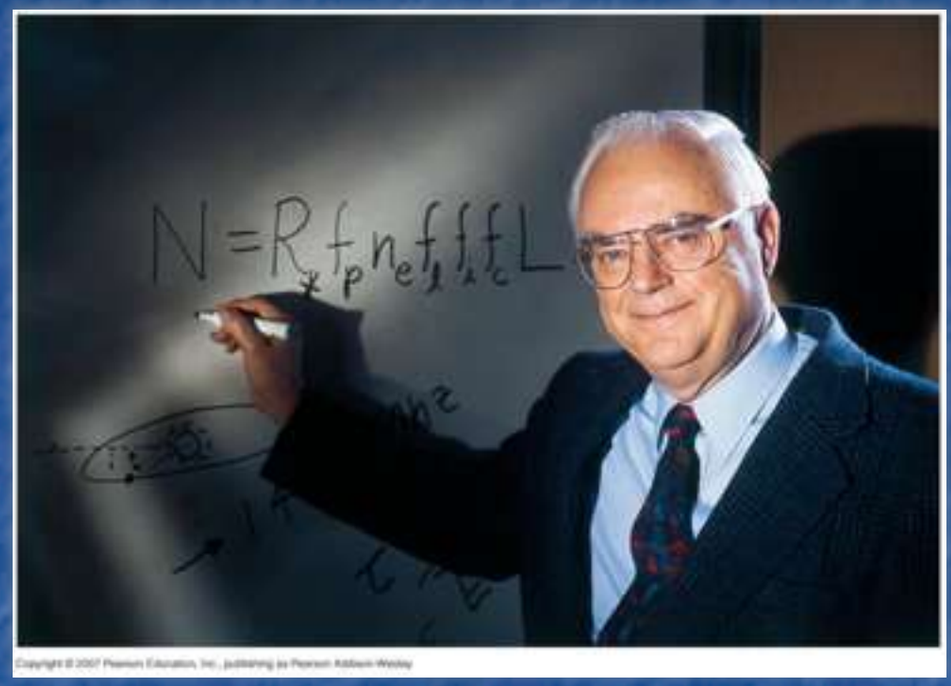
- Really it was USSR that dominated SETI in the 60's.

epsilon Eridani system



Drake Equation

- 1961, Estimate of the number of civilizations capable of sending signals currently present in the Milky Way?



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A modern version of the Drake equation

$$N = N_{HP} \times f_{life} \times f_{civ} \times f_{now}$$

- N = total # of detectable civilizations in Milky Way
- N_{HP} = # of habitable planets in the Milky Way
- f_{life} = fraction of habitable planets which have life
- f_{civ} = fraction of life-bearing planets where a civilization emerged capable of interstellar communications
- f_{now} = fraction of these planets which have the capability of sending signals now

example?

By DENNIS OVERBYE
Published: November 4, 2013

The New York Times

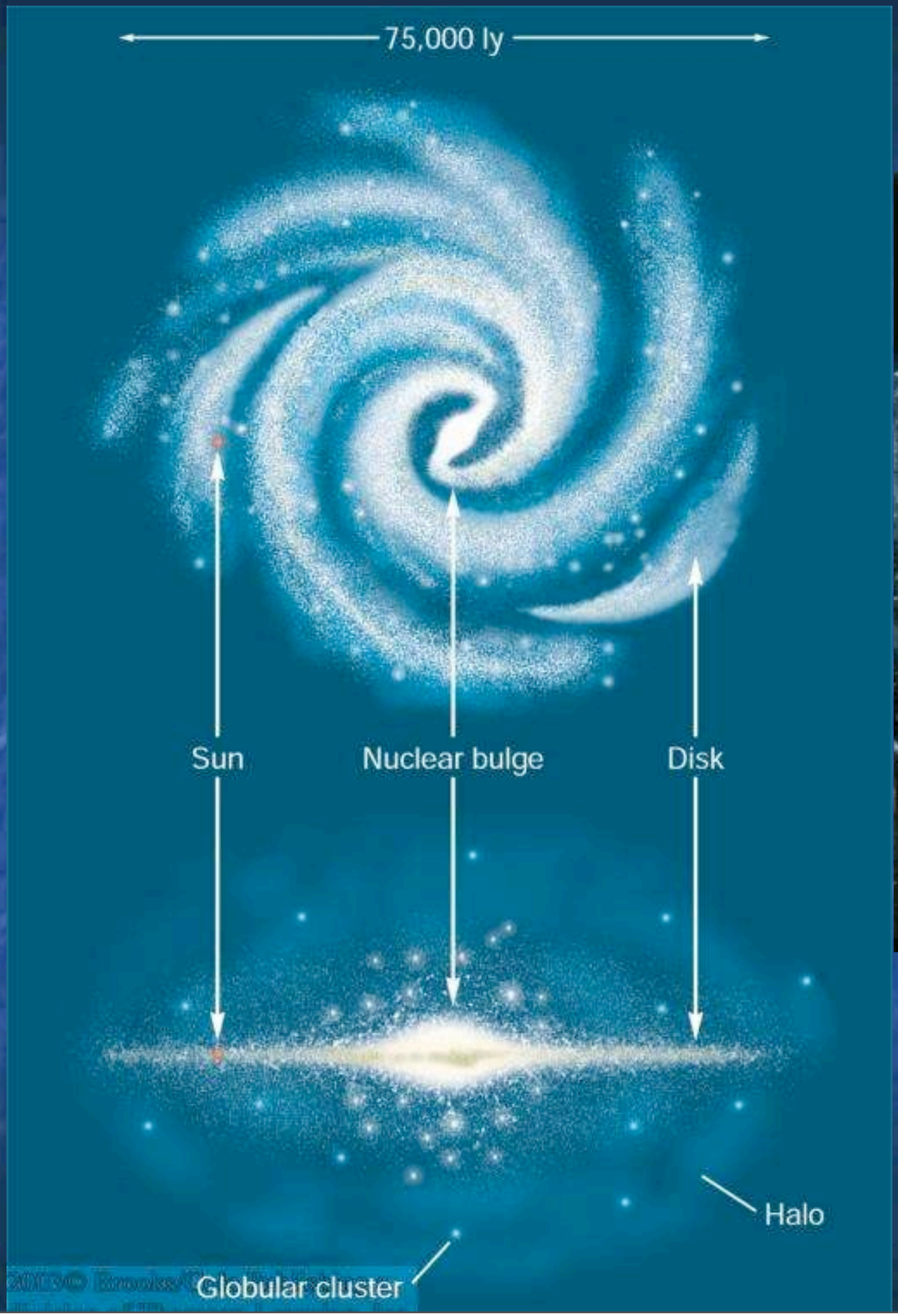
The known odds of something — or someone — living far, far away from Earth improved beyond astronomers' boldest dreams on Monday.

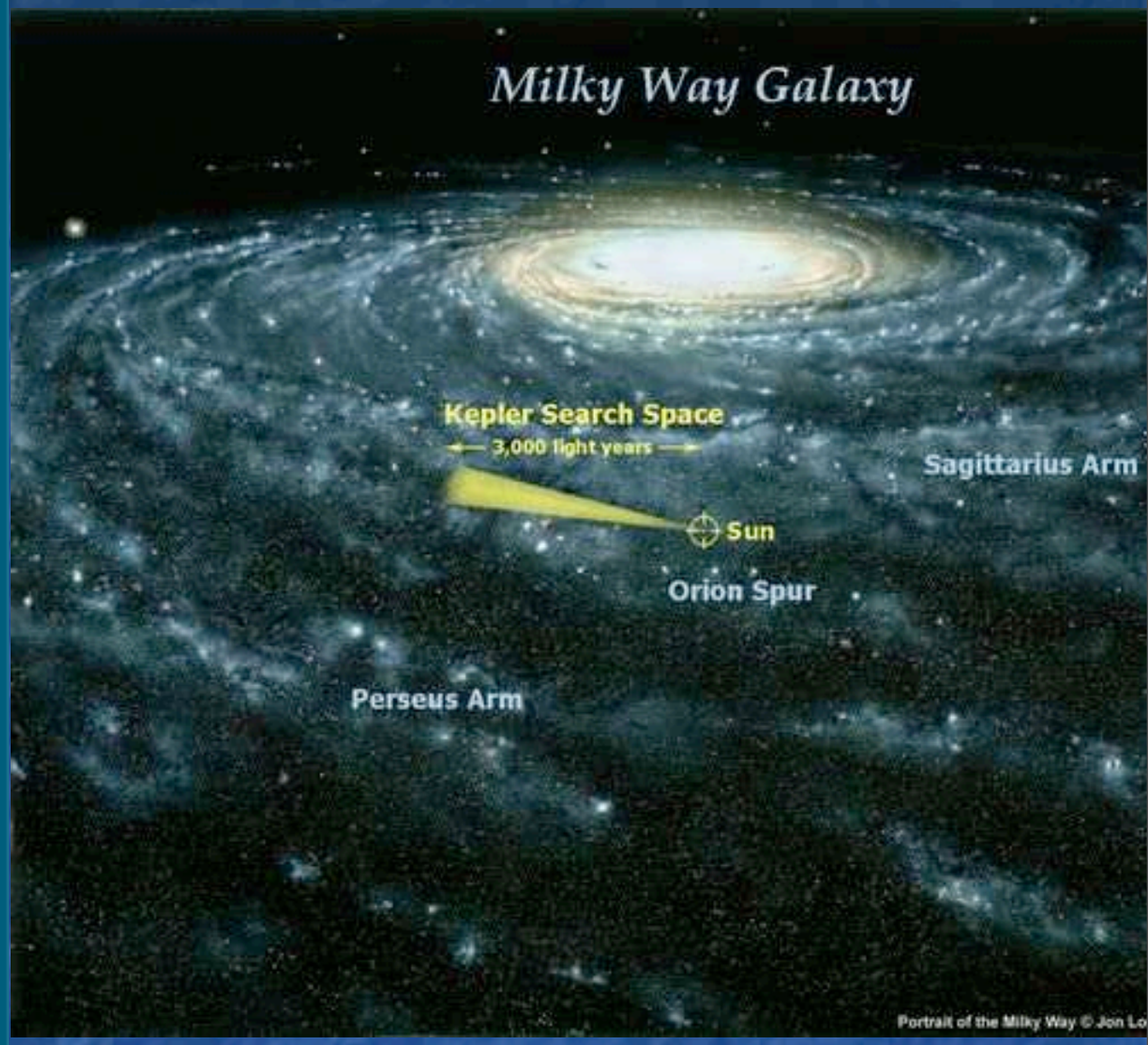
Astronomers reported that there could be as many as 40 billion habitable Earth-size planets in the galaxy, based on a new analysis of data from NASA's Kepler spacecraft.

One out of every five sunlike stars in the galaxy has a planet the size of Earth circling it in the Goldilocks zone — not too hot, not too cold — where surface temperatures should be compatible with liquid water, according to a herculean three-year calculation based on data from the Kepler spacecraft by Erik Petigura, a graduate student at the University of California, Berkeley.

Mr. Petigura's analysis represents a major step toward the main goal of the Kepler mission, which was to measure what fraction of sunlike stars in the galaxy have Earth-size planets. Sometimes called eta-Earth, it is an important factor in the so-called Drake equation used to estimate the number of intelligent civilizations in the universe.

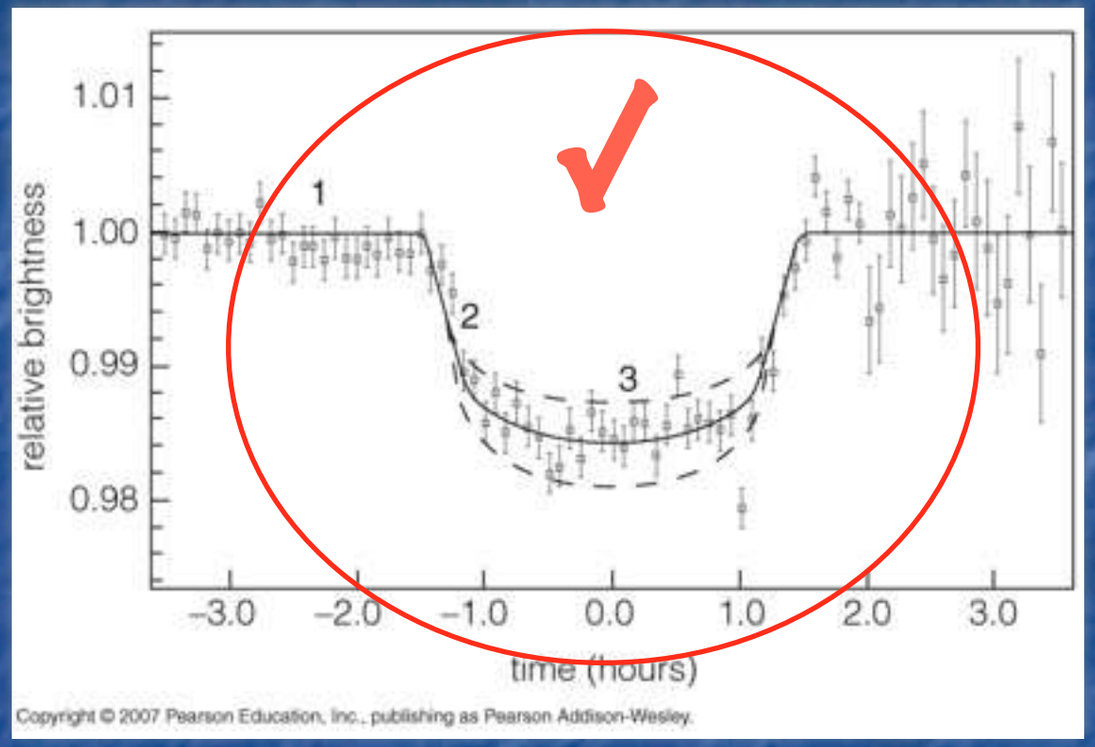
"It seems that the universe produces plentiful real estate for life that somehow resembles life on Earth," Mr. Petigura said ...





The size of the Sun symbol is about the size of our radio-loud sphere

How can we improve our estimates of the factors in the Drake equation?



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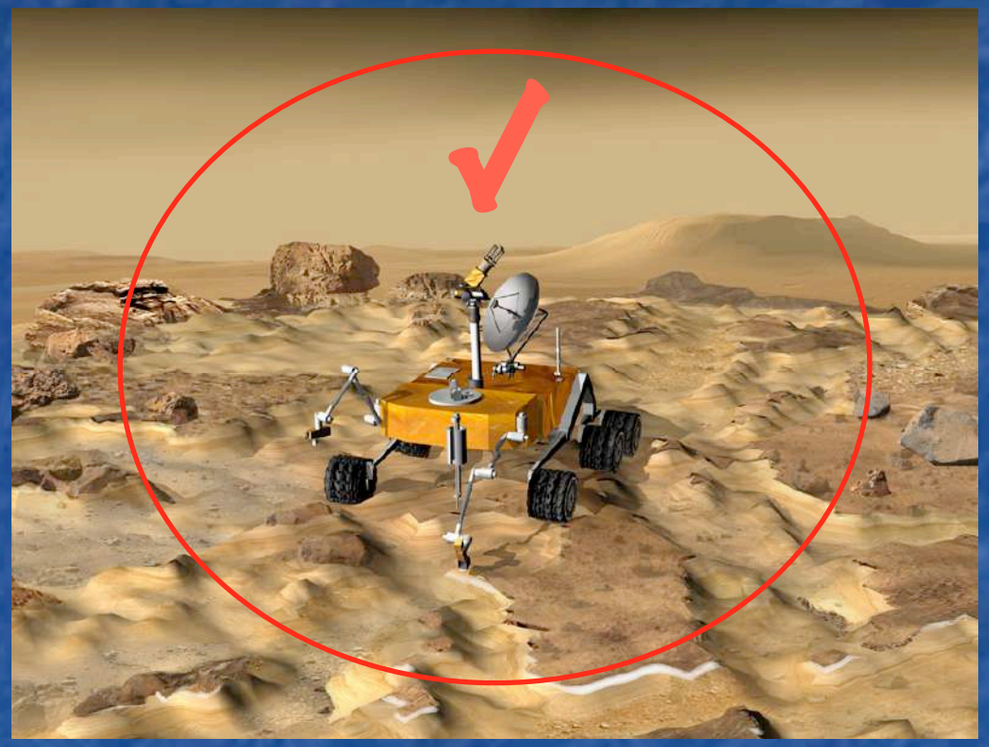
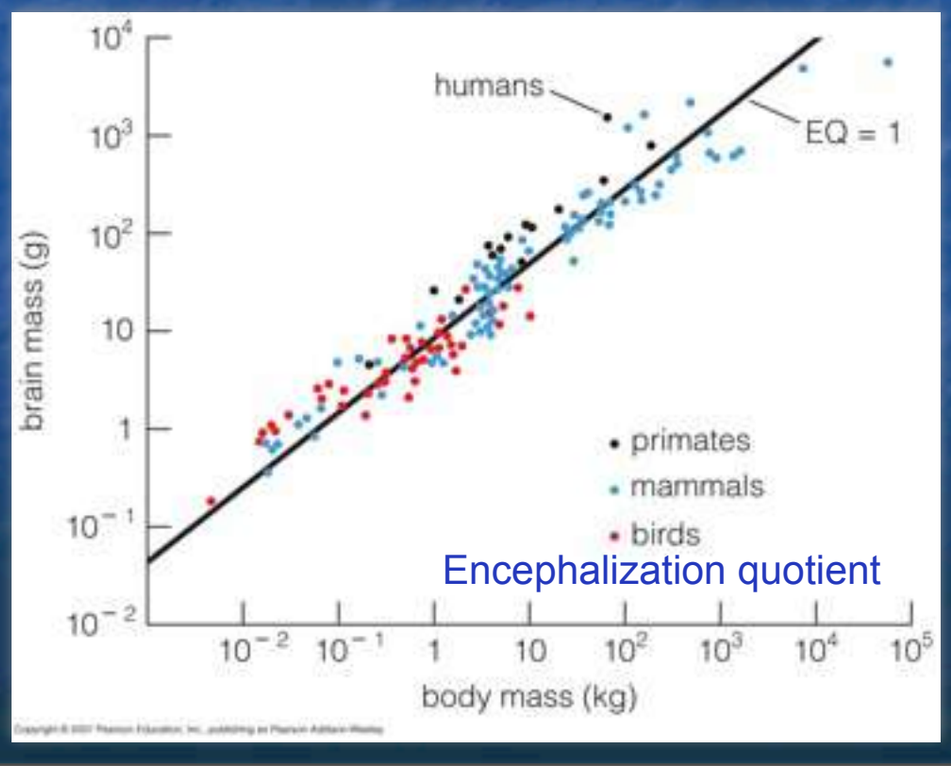
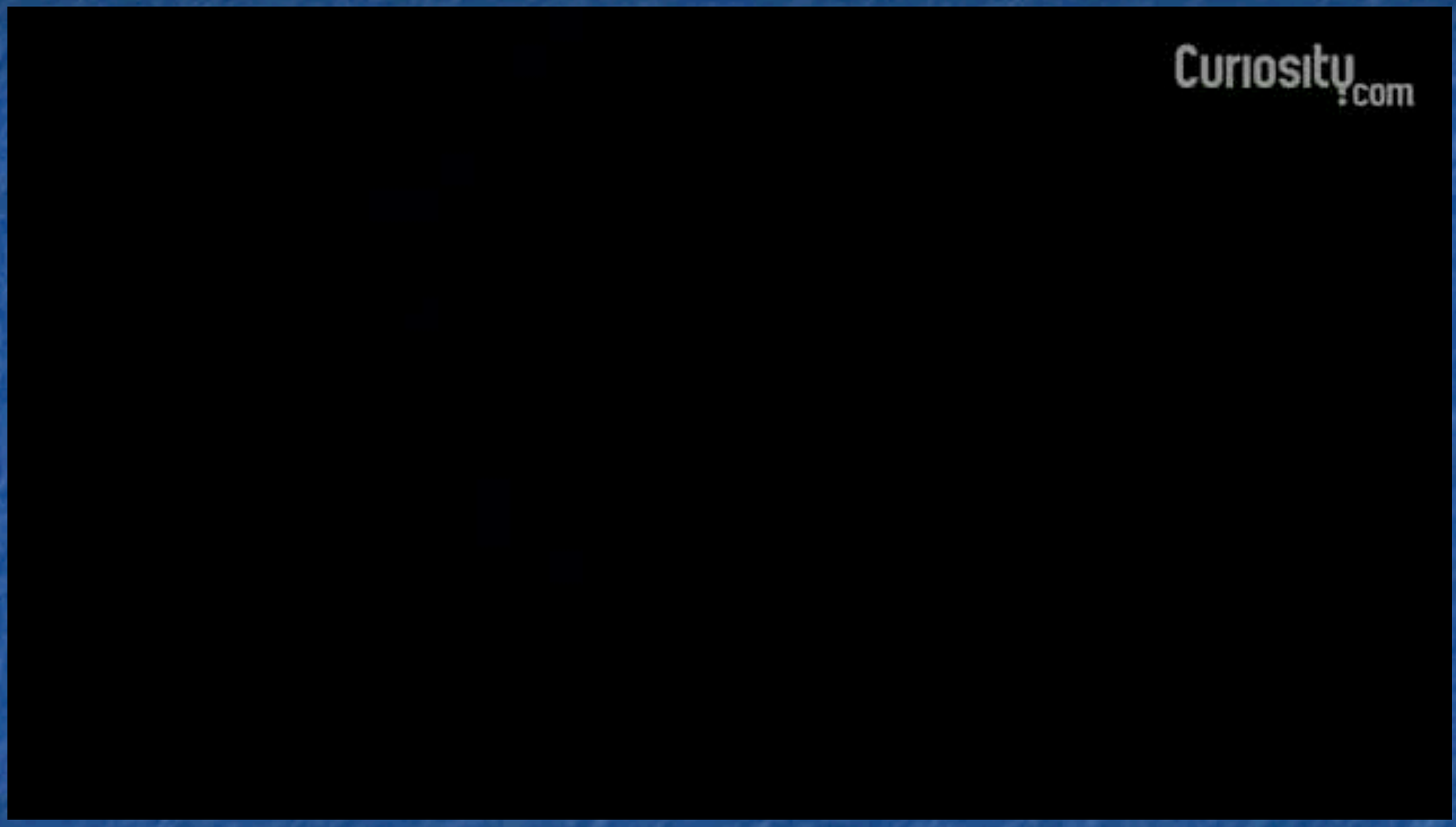




Encephalization quotient

Are we alone?



Jill Tartar
Director of the SETI Research Centre

How is SETI carried out?

How is SETI carried out?

- The primary method of searching for advanced civilizations is to try to detect signals
  - while most people think of SETI listening for these signals, sound cannot travel through empty space!
  - instead, SETI watches for signals (often using radio telescopes)

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- Most SETI projects are carried out using the radio part of the spectrum, though some is done in the optical too
- Confirmation that a signal is from an advanced civilization means ruling out other possible sources
  - human transmissions, satellites, airplanes, Fox News ...
  - natural sources which vary with time (thunderstorms, pulsars, ...)
  - random noise peaks

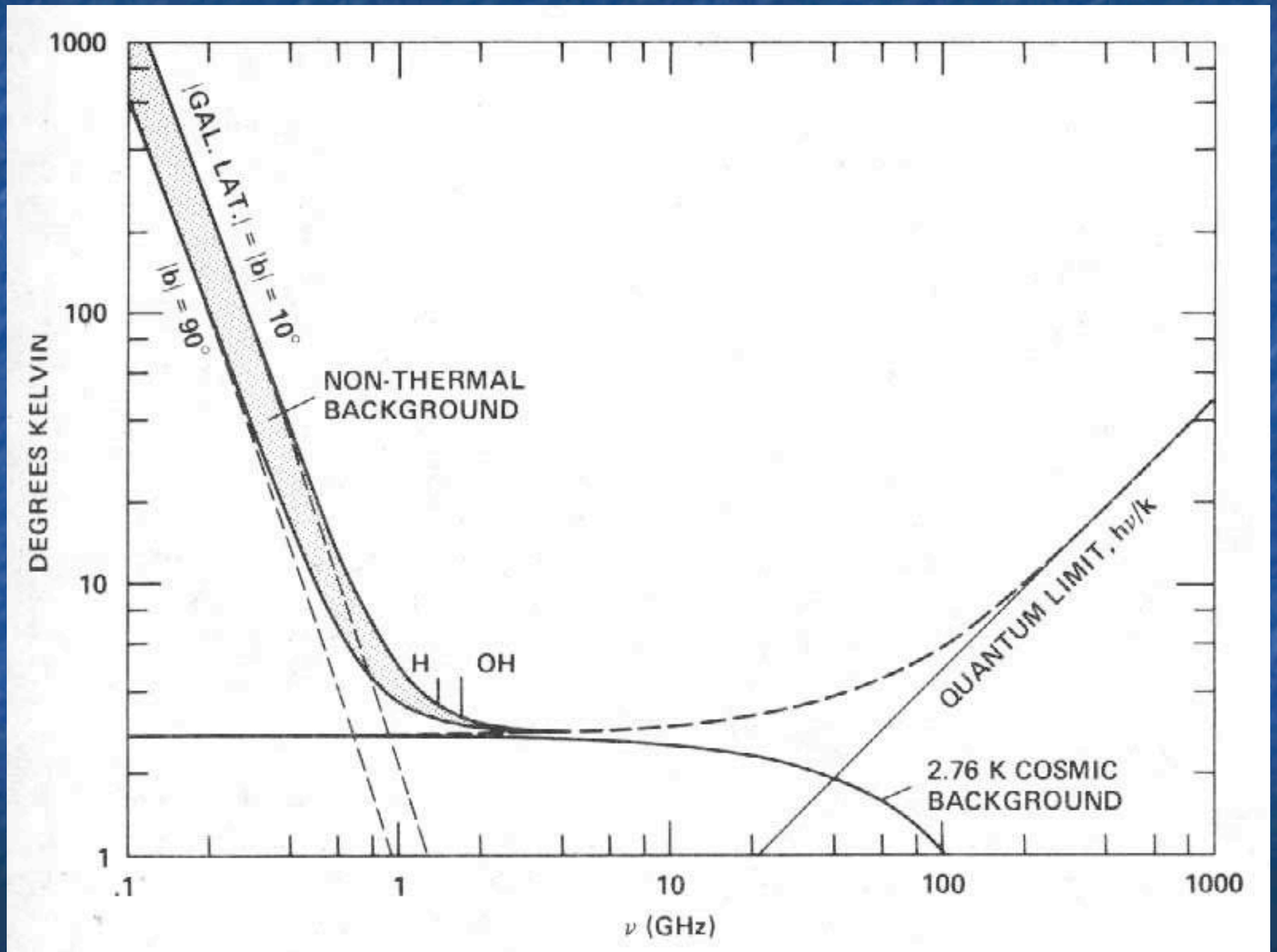
Search how?

- Potential signals may have a wide variety of properties, and therefore there are many factors to consider when carrying out a SETI search

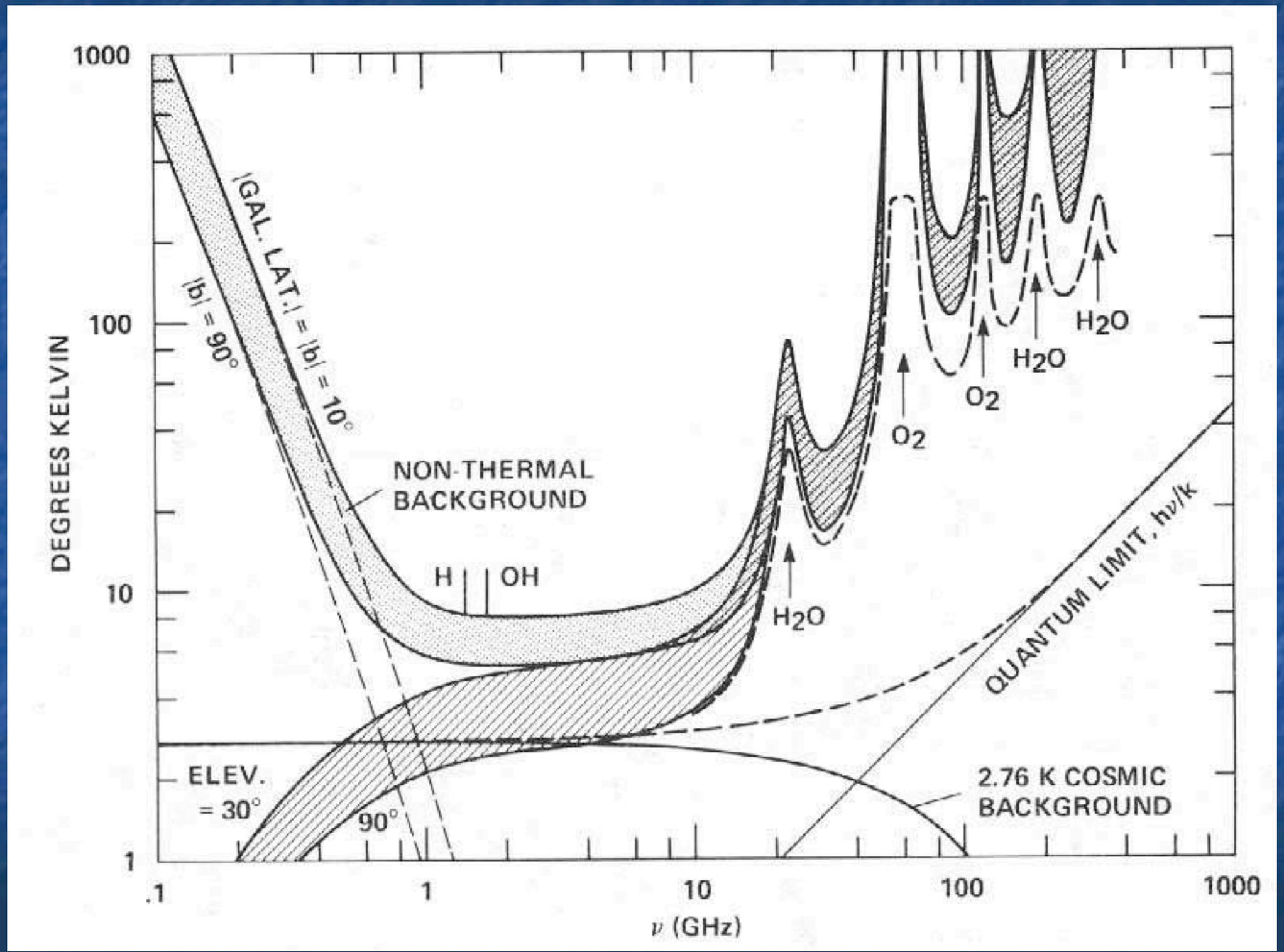
- Location on the sky
  - One approach is to target individual nearby Sun-like stars
  - Another is to map large swaths of sky in less detail

- The radio part of the spectrum is most popular, especially the 1420 MHz (21 cm) frequency due to HI emission
  - Width of frequency channel
  - Signal strength
  - Signal duration

The radio spectrum and the water window



The radio spectrum and the water window



Current Radio SETI Projects

TABLE 12.1 *Current Radio SETI Projects*

Name	*Institution*	*Telescope*	*Type*	*Total Number of Channels*	*Width of Single Channel*	*Band Covered*	*Detectable Power for 100-Meter Transmitter at 100 Light-Years*
Inner Galactic Plane Survey*	SETI Institute	Allen Telescope Array	Survey	450 million	1 Hz	1,390–1,720 MHz	70 megawatts
SERENDIP	University of California, Berkeley**	Arecibo Radio Telescope (305 m)	Sky Survey	168 million	0.6 Hz	1,370–1,470 MHz	1 megawatt
Southern SERENDIP	SETI Australia Centre	Parkes Radio Telescope (64 m)	Sky Survey	58 million	0.6 Hz	1,418–1,421 MHz	1 megawatt
SETI Italia	Istituto di Radioastronomia, Bologna	Medicina radio telescope (32 m)	Sky Survey	24 million	0.6 Hz	Bands centered at 1.4, 2.8, 6.4, and 22.4 thousand MHz	Typically 30 megawatts

* Values given here are for the Allen Telescope Array capabilities at the end of 2006, when it will have 42 of its 6-meter antennas in operation. As more antennas are added (eventually reaching a total of 350), the sensitivity will increase and the observing mode will switch to a targeted search of stars within 1,000 light-years.

** About 2.5% of the data collected by the SERENDIP project is being distributed over the Internet for processing on a downloadable screen saver. This project (called SETI@home) has involved more than five million home computer users.

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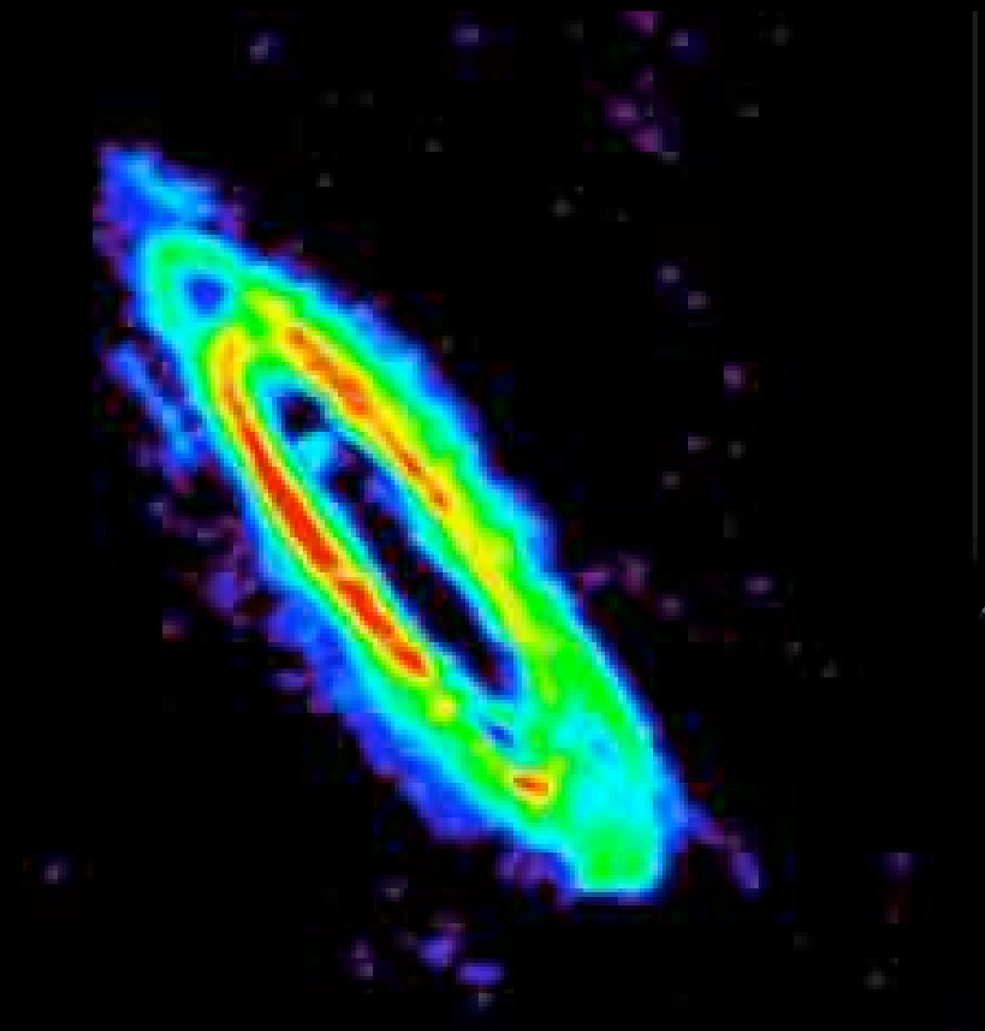
The Allen Telescope Array

- 1992, but stalled
- Will consist of 350 6-metre radio telescopes in Hat Creek, California
  - 42 of these telescopes are now active

- Primarily funded by Paul Allen (co-founder of Microsoft)
- Will be used for SETI and for other radio astronomy projects

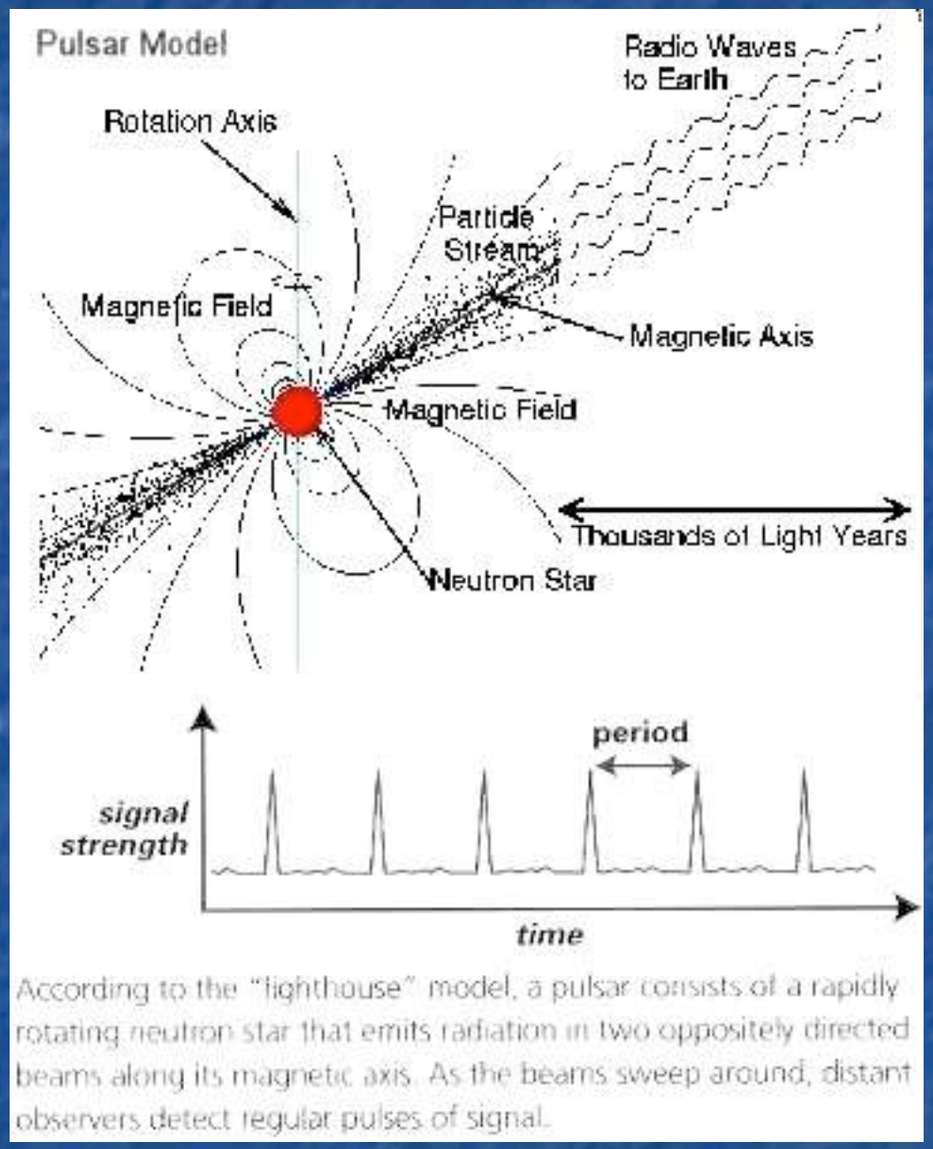
First Image Taken by the Allen Telescope Array



Radio

Optical

Periodic Radio Signals: LGM vs Pulsars

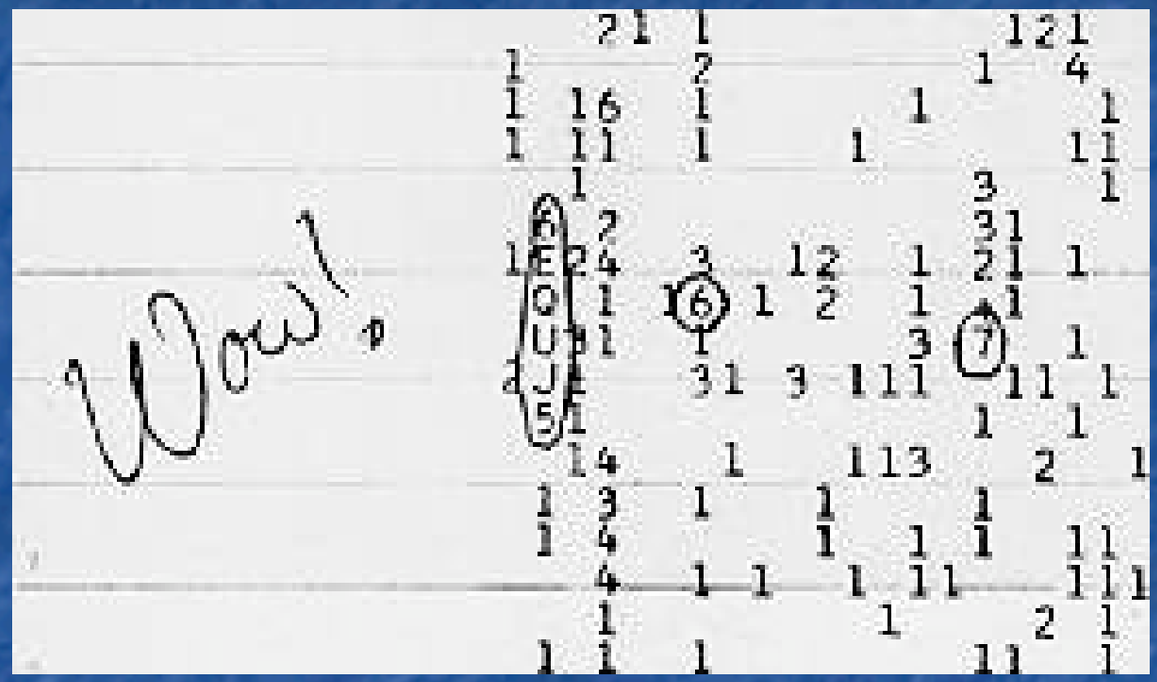


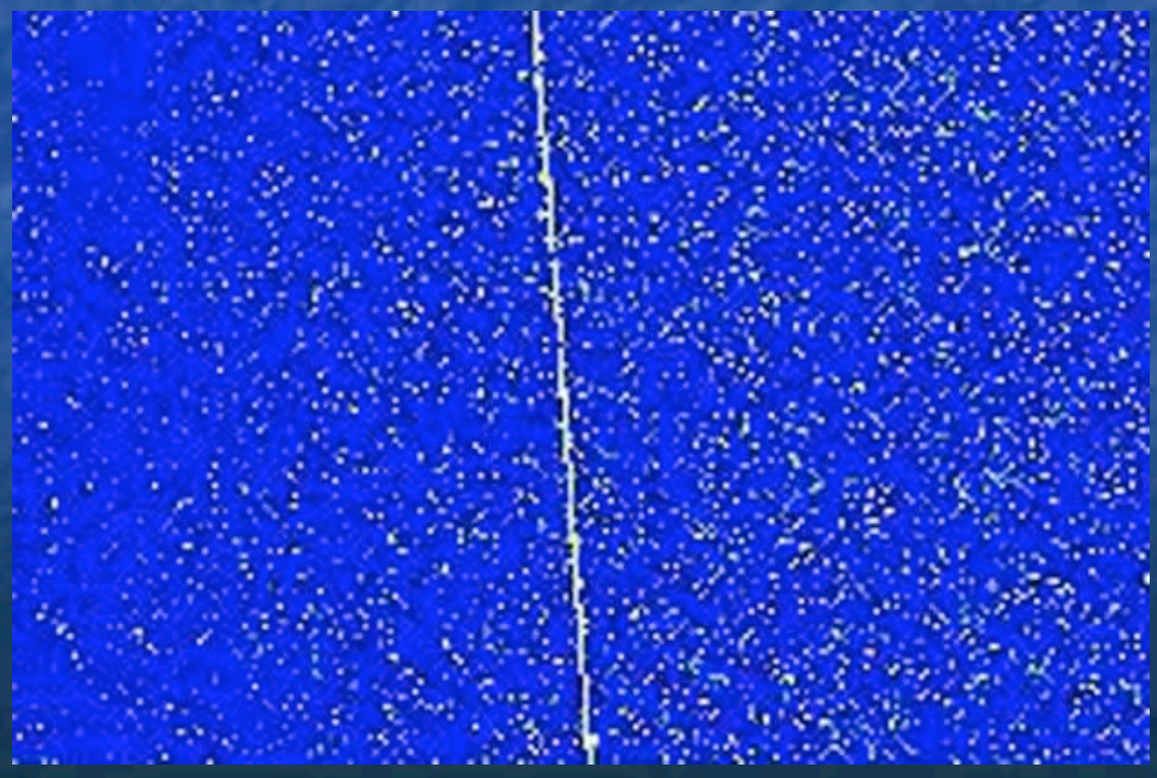
According to the "lighthouse" model, a pulsar consists of a rapidly rotating neutron star that emits radiation in two oppositely directed beams along its magnetic axis. As the beams sweep around, distant observers detect regular pulses of signal.

- Detected as a periodic radio signal in 1967.
- Signal detected at 0.74 Hz.
- Labelled (playfully) as LGM (Little Green Men) 1.
- Upon announcing the signal as arising from an unknown class of astronomical object, Fred Hoyle almost immediately identifies it as a rapidly rotating neutron star - dubbed a pulsar.

Any Detections Yet??

- There have been no confirmed SETI detections to date
- There have been a number of possible detections
- Many "false positives" occur due to human activity
  - satellites, planes, radar, etc.





The Wow Signal (1977)

Some Review Questions

- Try Chapter 12, Q 6, 8-11, 13, 14

  e.g., Q8 "Why do SETI researchers believe beacon signals would be designed for easy decoding, and how would we recognize them?"

- Also, Evaluate these Opinions: Q 15, 17 -21

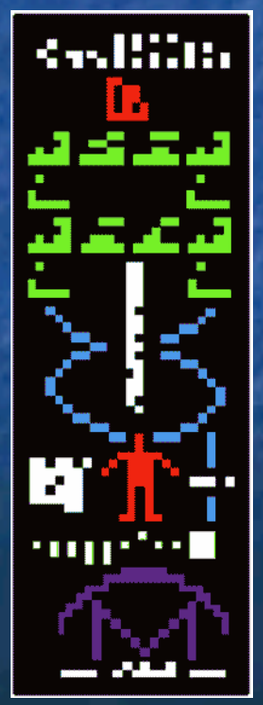
  e.g., Q15 "Humans are the 'crown of creation' and an inevitable result of billions of years of evolution"

- And, Quiz questions: Q 25 - 34

  e.g., Q32 "Two -way conversations with other societies is unlikely even if we make contact because (a) language issues, (b) dangerous to keep in contact, (c) takes too long for messages to be relayed?

Can they detect us?

- Other civilizations may be able to detect signals from us (and reply!)
- We have been broadcasting TV (and other signals) outwards from the Earth for < 100 years
- Only the very closest stars could receive and reply to these transmissions within our lifetime



The Arecibo radio observatory: 300m diameter radio dish

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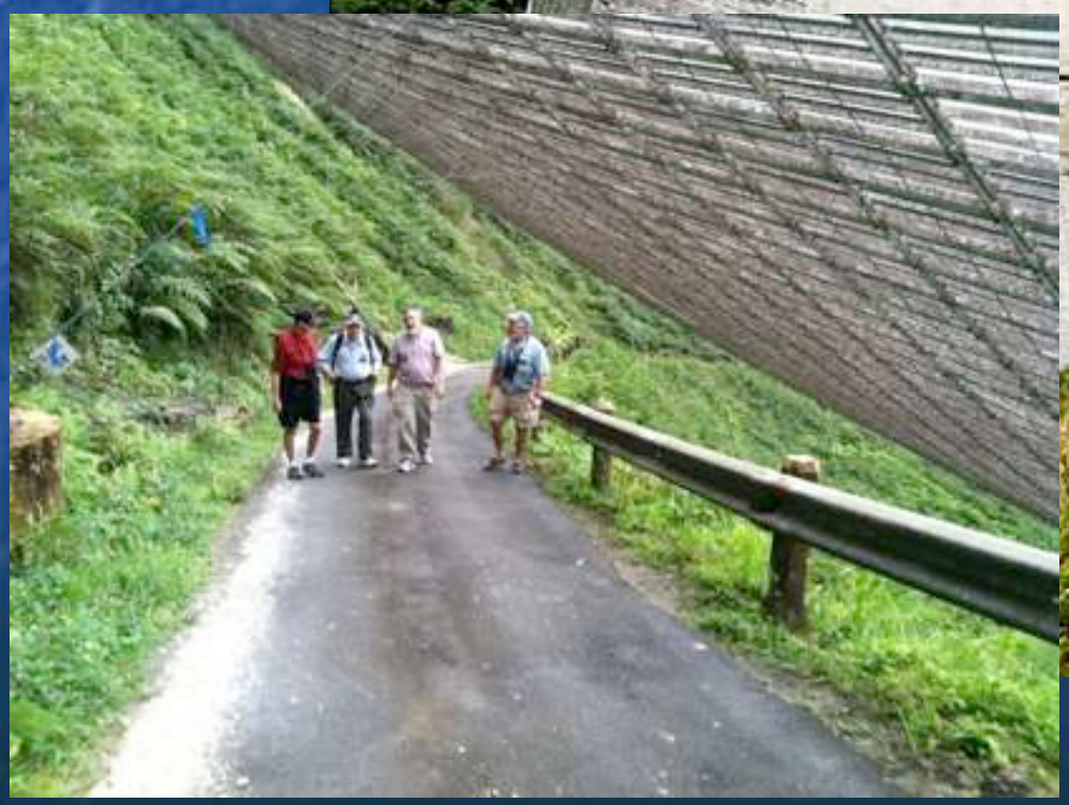
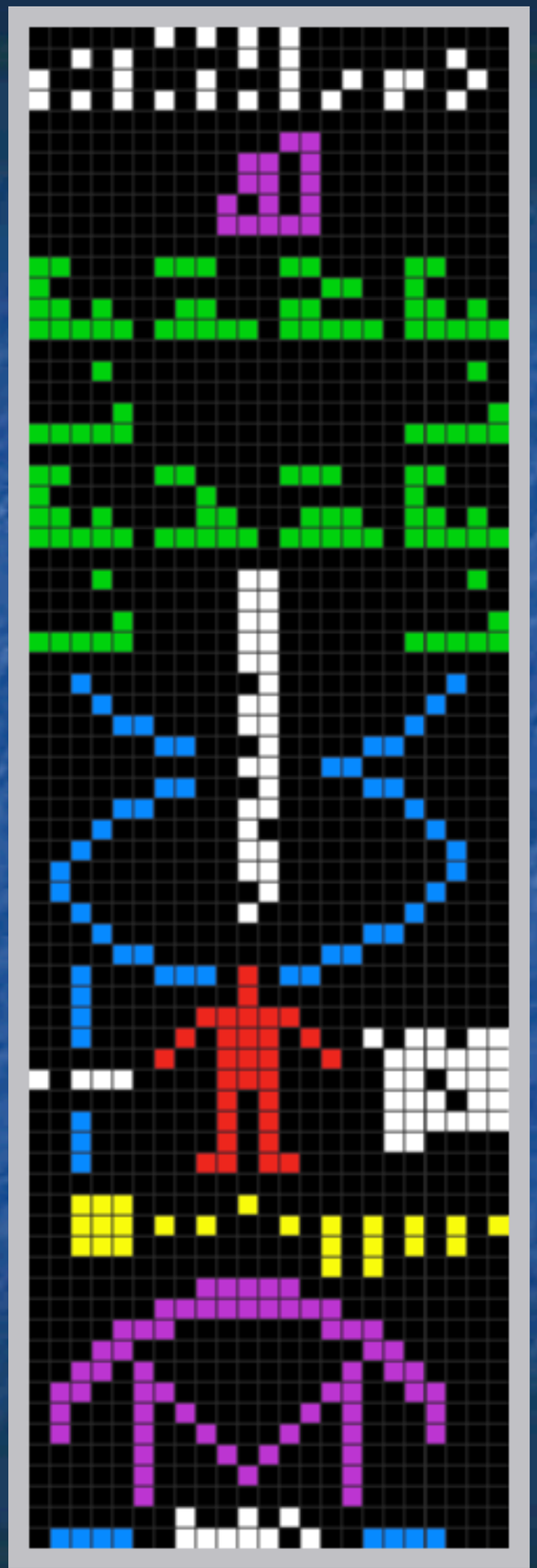
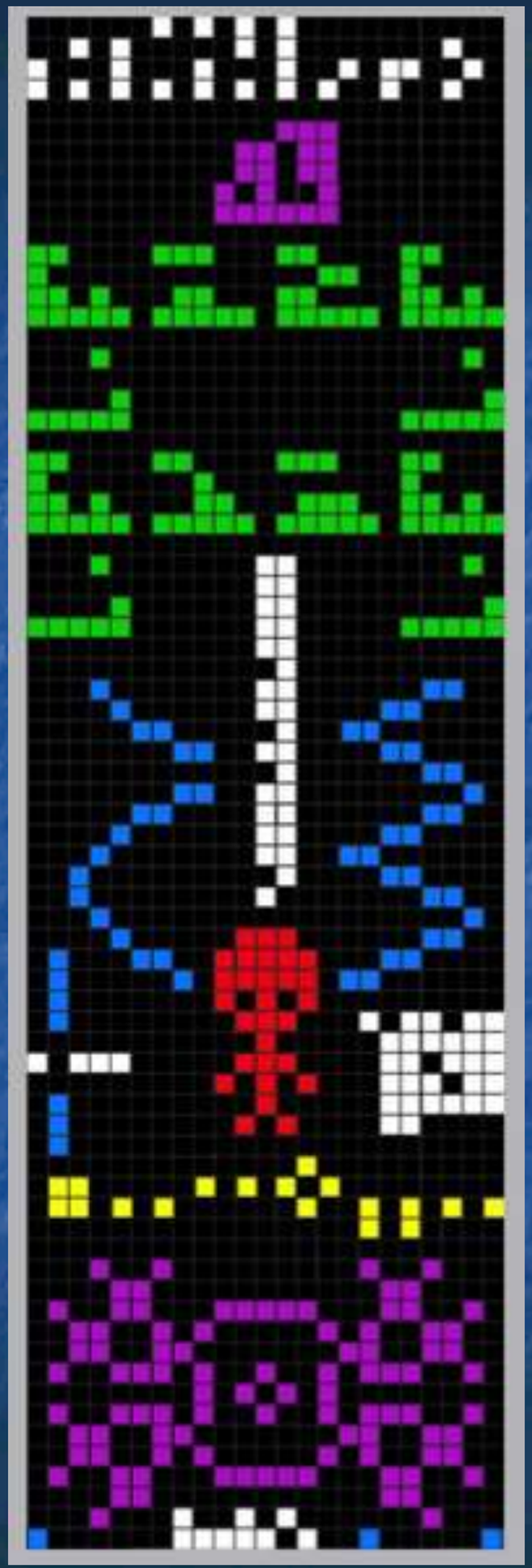


The Arecibo message

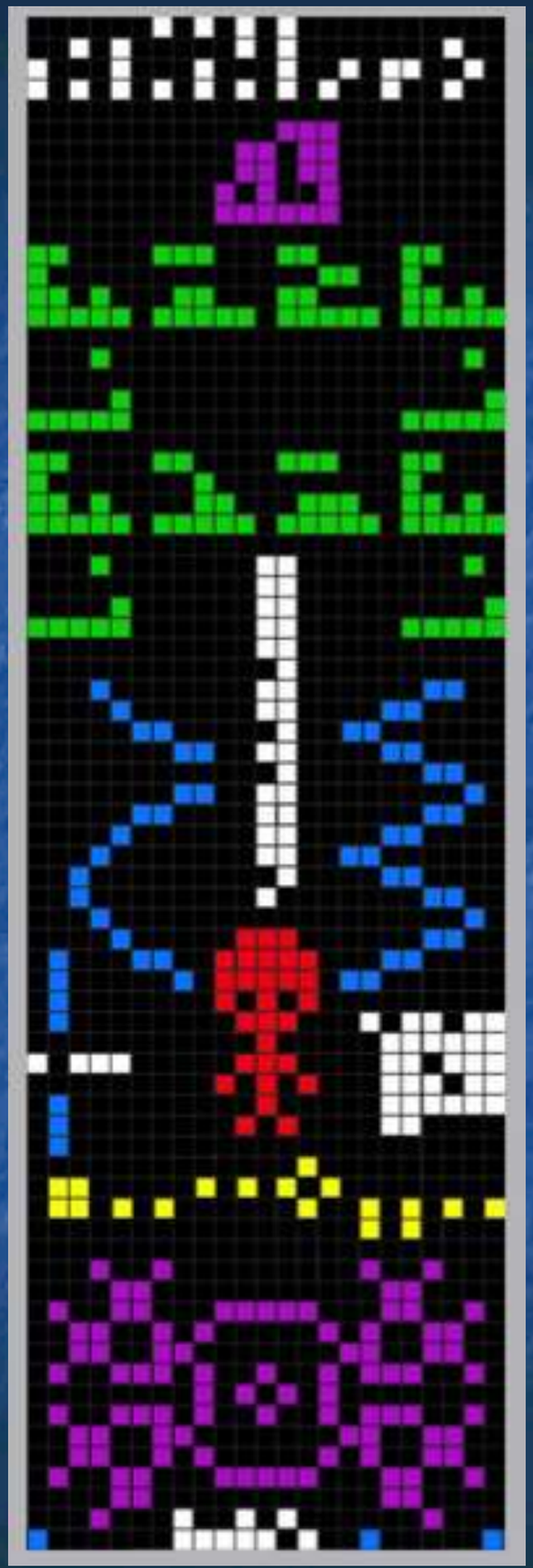
- Beamed to the globular cluster M13 on 16 November 1974.
- M13 is 25,000 Ly away.
- The signal consisted of 1679 digits amounting to 210 bytes of information.
- Transmitted at 2320 MHz with 1 MW of power.
- 1679 is a semi prime number equal to 23x79.
- Re-arranging the digit stream as a 23x79 rectangle reveals the "message"



- The numbers one (1) through ten (10)
- The atomic numbers of the elements hydrogen, carbon, nitrogen, oxygen, and phosphorus, which make up deoxyribonucleic acid (DNA)
- The formulas for the sugars and bases in the nucleotides of DNA
- The number of nucleotides in DNA, and a graphic of the double helix structure of DNA
- A graphic figure of a human, the dimension (physical height) of an average man, and the human population of Earth
- A graphic of the Solar System
- A graphic of the Arecibo radio telescope and the dimension (the physical diameter) of the transmitting antenna dish



- Our attempts at communication are not always taken seriously.
- The Arecibo reply message took the form of a crop circle discovered close to a UK radio telescope in 2001.
- It does raise the question though, "why did we send the original message"?
- In the 25,000 years taken for the signal to reach M13, the globular cluster will have moved out of the original beam and the signal will miss the target.
- The 1974 message was more of a demonstration of what is possible/ publicity stunt than a serious attempt at communication.



2001, Chilbolton radio telescope in Hampshire, UK

Have aliens been here already?

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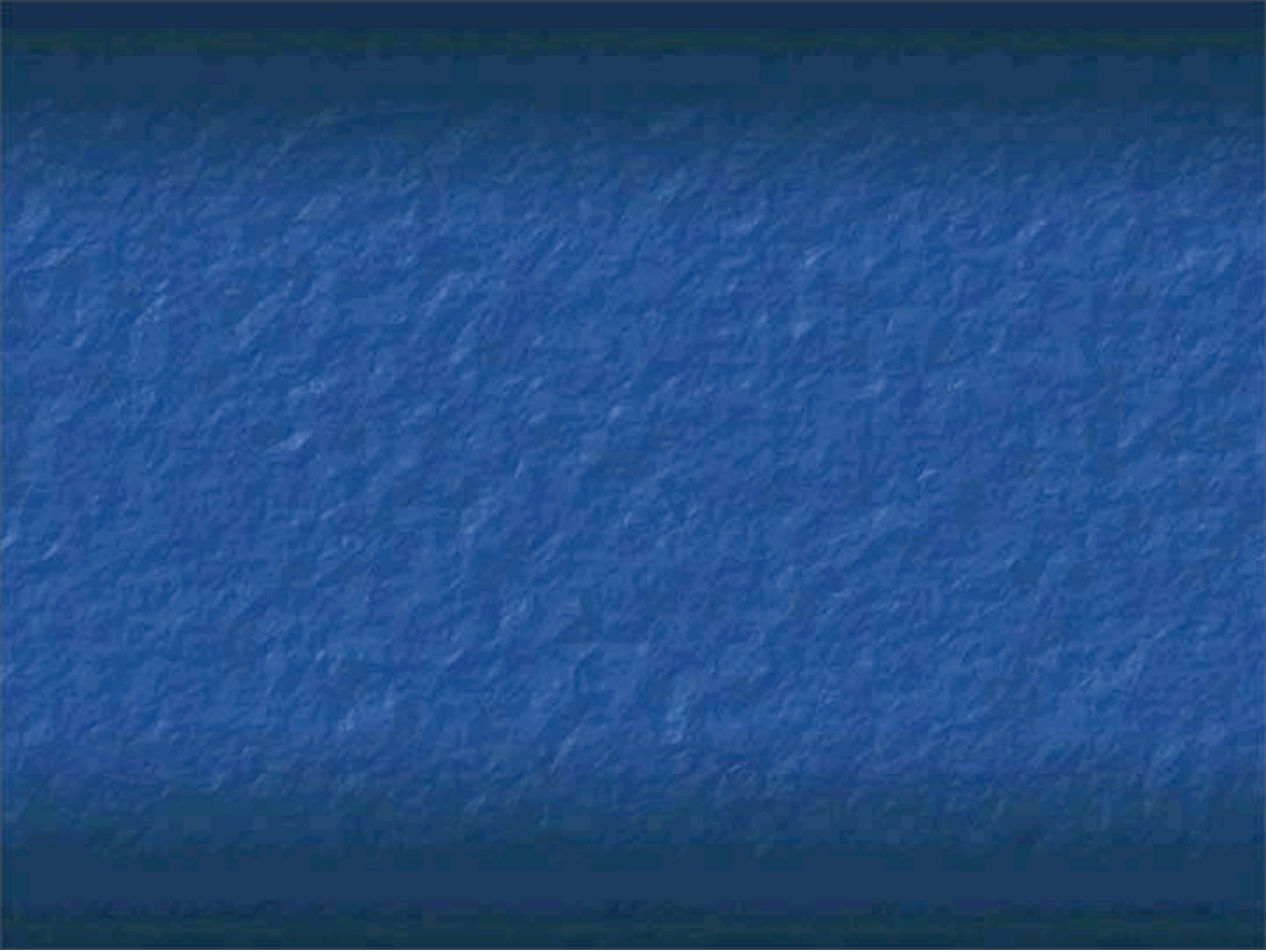
The context of SETI within the scientific community

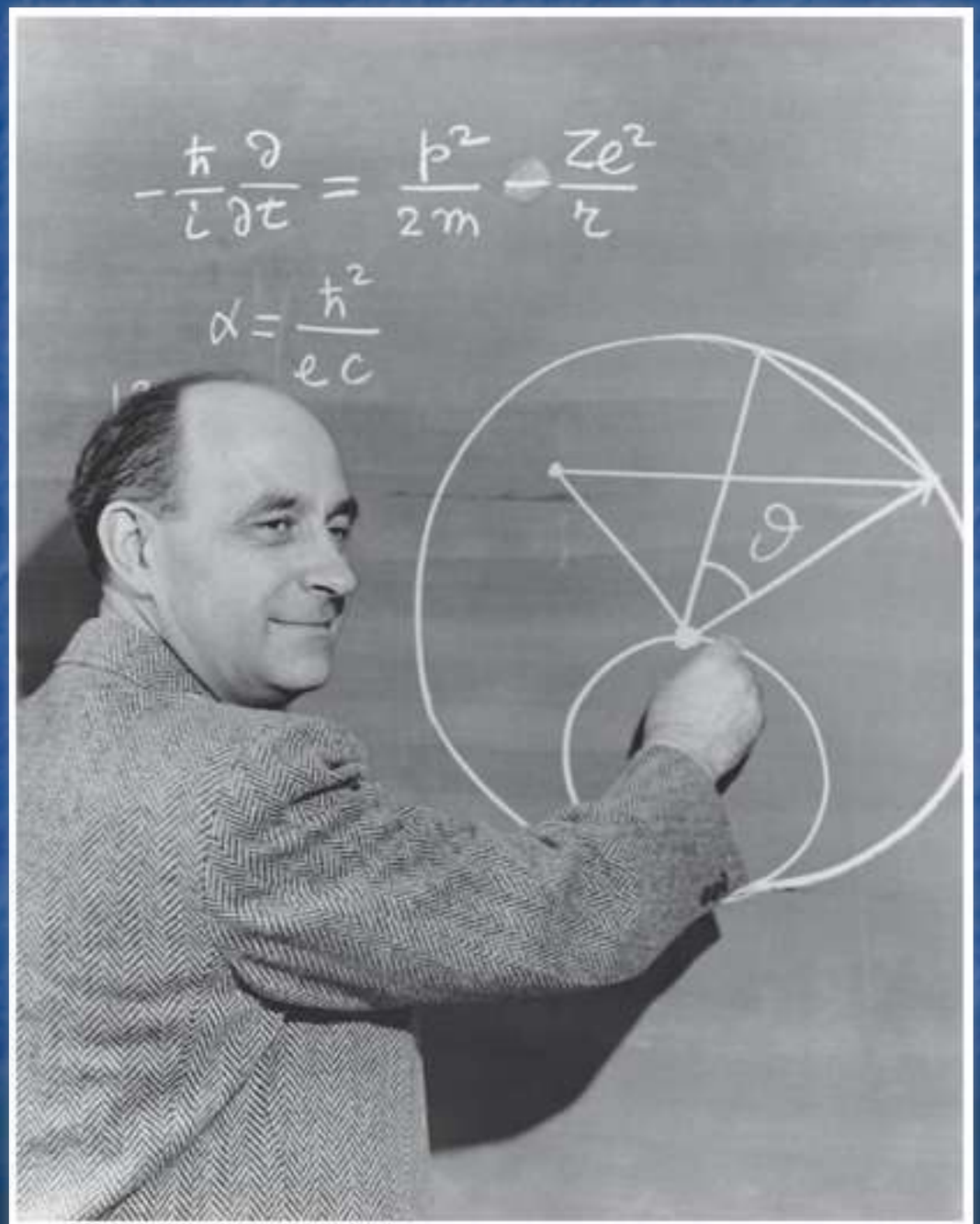
- "The probability of success is difficult to estimate; but if we never search, the chance of success is zero."
  Morrison and Cocconi, Nature, 1959
- Should a SETI experiment detect an alien civilisation the results will have a tremendous social and scientific impact.
- But what do we learn if SETI experiments continue to discover nothing?
- A number of scientist have questioned (some vehemently) whether this is "worthwhile" science.

What would we do with a signal?



The Fermi Paradox

- Given time, it seems likely that an advanced civilization should be able to colonize the Milky Way
- Assuming Earth is not special, other advanced civilizations should have arisen in our galaxy
- So, where is everybody?
- This is the Fermi paradox



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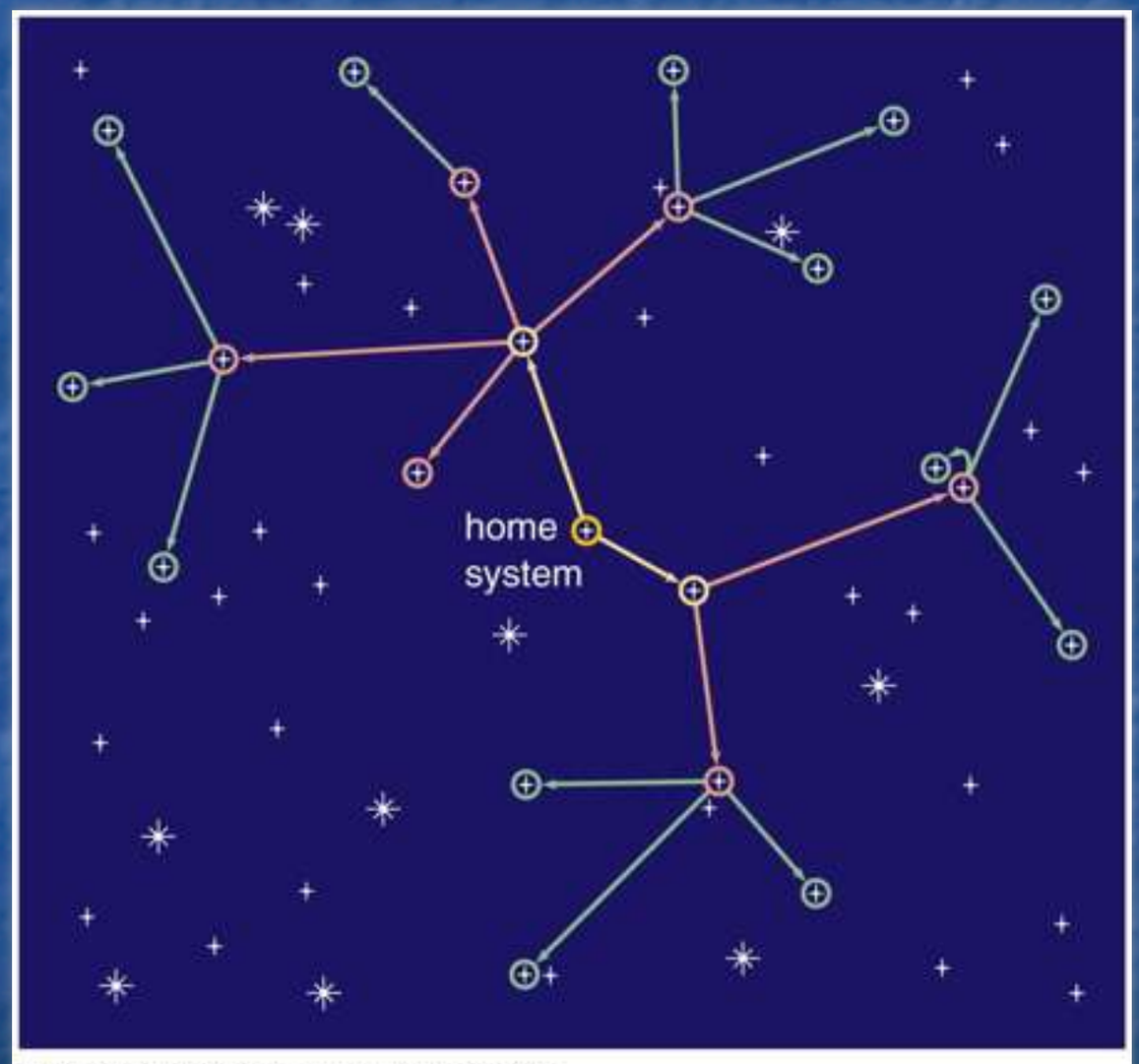
Colonization

- If advanced civilizations last for many thousands or millions of years, most should be much more advanced than we are
  - we've only been capable of space travel for about 50 years
- Even at modest speeds of travel, they should be able to colonize the Milky Way in well under a billion years



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Possible Explanations of the Fermi Paradox

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- We are alone
  - or at least, the first to arise in the Milky Way
- Civilizations are common, but no one has colonized the Galaxy, because
  - it is too challenging technologically
  - they choose not to
  - civilizations always destroy themselves early on

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  - it is too challenging technologically
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  - civilizations always destroy themselves early on
- There is a Galaxy-wide civilization, but we haven't found it yet
  - perhaps they are even deliberately staying hidden

Some Related/Alternative Explanations

- They are already here
- They have been here in the past
- Everyone is listening, but no one is signalling
- Intelligence is extremely rare
- Etc.!

What Steps Can We Take Towards Resolving the Fermi Paradox?

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- SETI
  - if successful, we would resolve the paradox by establishing the existence of other civilizations in the Milky Way
- Detection of habitable extra-solar planets
  - In principle, we should be able to make a much better estimate of how common Earth-like planets are
    - if they turn out to be very rare, this would help to explain the paradox (with the "We are alone" option)
  - Even better, if we detect signs of life, we will know life is common

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  - Even better, if we detect signs of life, we will know life is common
- Detection of independently arising microbial life in the solar system
  - this would imply that life is common throughout the galaxy, and therefore that other civilizations are more likely to exist
- Long term human survival
  - if we can survive climate change, nuclear war, etc., we will know it is possible for other civilizations to survive too